The acute effect of a foam rolling and a dynamic stretch warm-up routine on jumping performance

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Abstract

Background: Self-myofascial release is widely used by athletes but the scientific evidence of its supposedly positive effects is limited. This study was conducted to investigate the effects of foam rolling as a warm-up routine in comparison with a dynamic stretching routine and how it may affect the jumping performance among subjects familiar with weight training.

Aim: The aim of this study was to investigate the acute effect of foam rolling vs. a standardized dynamic stretch warm-up routine on jumping performance.

Method: Twelve subjects, mean (SD) age 25.1 (± 3.0) years, participated in a randomized, controlled, crossover study. All subjects completed a standardized foam rolling (FR) and a dynamic stretch (DS) warm-up routine on separate days of testing. Squat jump (SJ), counter movement jump (CMJ) and loaded counter movement jump (L-CMJ) all performed bilaterally and unilaterally were conducted to investigate the acute effect of the two warm-up routines. A dependent T-test was used to investigate differences between the warm-up routines.

Results: A statistical significant difference in favor of the DS was found for SJ performed bilaterally among males (p = 0.009). The mean (SD) jumping height for SJ FR was 35.6 (± 4.7) cm and for SJ DS 37.9 (± 5.2) cm. The male group also improved more in L-CMJ performed on the right leg with an external load of 54kg after DS compared to FR. No other statistical significant differences were found between the two interventions. A near statistical significant difference was found for SJ performed bilaterally for the total sample (p = 0.057) also in favor of the DS. The mean (SD) jumping height for SJ FR was 29.3 (± 8.7) cm and for SJ DS 30.5 (± 9.9) cm.

Conclusion: Findings from this study supports a dynamic stretch warm-up routine prior to performing high intensity bilateral plyometrics instead of a foam rolling warm-up routine. However the data was inconsistent and more research with larger sample sizes is needed to further investigate the possible effects of foam rolling as a warm-up routine on jumping performance performed both bilaterally and unilaterally.
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Introduction

Self-myofascial release in general and foam rolling in particular has become a common tool in gyms and training facilities. The implementation of foam rolling as a warm-up routine is widely used among athletes and coaches and it has become a common routine among recreational athletes as well. Despite the widely spread use of the method the scientific evidence of the effects of self-myofascial release and foam rolling is limited. This study was conducted to investigate the supposedly positive effects of foam rolling as a warm-up routine and how it may affect the jumping performance among subjects familiar with weight training. This study hopes to further bring interest into the area and hopefully lead to more research and a better understanding of the physiology and effects of self-myofascial release.

Background

Fascia

The fascia is connective tissue that surrounds the body from head to toe. It surrounds every muscle, bone, nerve and organ down to the cellular level. The fascia is further categorized into three subcategories. Fascia superficialis is the most superficial of the three located just beneath the skin. It serves as a passway for nerves and blood vessels and its main function is protection and support. The second layer is the fascia profunda which invests muscles and other internal structures. The third is the deepest fascia and is also known as the dural tube. It surrounds and protects the brain and the spinal cord (Lindsay and Robertson, 2008).

The fascia is morphologically and functionally different in different parts of the body. The fascia lata in the thigh is relatively autonomous in its structure while the pectoralis fascia acts as an additional insertion for the pectoralis muscle. In the trunk the fascia consist of a single layer of undulating collagen fibers mixed together with elastic fibers while in the thigh the deep fascia is independent from the muscle separated by epimysium and a layer of connective tissue. The fascia lata is easily recognizable while the pectoralis fascia are in continuity with the muscle fibers of the pectoralis nuchle (Findley et al., 2012).

Fascia is a complex and continuously improving area of research. Schleip (2012) explains fascia as a soft component of the connective tissue. The tissue functions as a part of a body wide tensional force transmission system (Schleip et al., 2012, Huijing and Jaspers, 2005).
The fascia acts as an innervated, continuous, functional organ creating stability and motion throughout the human body (Kumka and Bonar, 2012).

**Myofascial release**

Exercise induced stress on the fascia may lead to myofascial restrictions. The restrictions include central and attachment trigger points as well as muscle contractures and fascial adhesions (Fredericson and Wolf, 2005).

Following acute inflammation fascia may tighten and lose its pliability. When the inflamed fascia tightens pain occurs and normal blood circulation is suppressed (Findley et al., 2012).

Myofascial release may release pressure on the affected area and restore normal blood flow in the tissue (Findley et al., 2012). Other studies show similar positive results in the treatment of pain (Miernik et al., 2012) and blood flow restrictions (Walton, 2008). Research also indicates positive effects of myofascial release treatment on headache (Ajimsha, 2011) and triceps surae dysfunction (Grieve et al., 2013).

Myofascial release is a broad term consisting of a wide variety of techniques including osteopathic soft-tissue techniques, structural integration, massage, the trigger point technique and fascial release using different instruments (Simmonds et al., 2012). The purpose of myofascial release is to address localized tightness in the fascia (Findley et al., 2012).

Exactly how myofascial release affects tightness in the fascia is not clear. The effects of the pressure and stretch, which may create heat and friction in the tissue, could plausibly cause an alteration and softening of the tissue. This occurs when loosening of cross-links between the collagen fibers and a microfailure of these follow (Simmonds et al., 2012). However the pressure exerted by manual therapists is not enough to cause an alternation in the tissue (Simmonds et al., 2012, Martínez Rodríguez and Galán del Río, 2013). In fact, it was found that forces outside the normal physiological range is needed to produce even 1% compression and 1% shear in the fascia lata and the plantar fascia (Chaudhry et al., 2008). It seems as a neurophysiological explanation could be more possible. During myofascial release interstitial receptors in the fascia (Martínez Rodríguez and Galán del Río, 2013) and receptors in the epimysium (Simmonds et al., 2012) are stimulated and leads to a decrease in muscle tension (Simmonds et al., 2012, Martínez Rodríguez and Galán del Río, 2013).
The perception of pain, defined as the sensory, motor and autonomic symptoms, is known as Myofascial Pain Syndrome (MPS). MPS is caused by myofascial trigger points (MTrPs) (Lavelle et al., 2007). MTrPs develop after muscle overuse where several factors should be taken into consideration. Eccentric overload and sustained concentric contractions as well as local ischemia could be factors contributing to the development of MTrPs. Indications of an inflammation in MTrPs has been observed as disruptions of the cell membrane, damage to the sarcoplasmic reticulum and the release of high amount of calcium ions as well as the presence of cytokines (Bron and Dommerholt, 2012). Another factor is the excessive release of acetylcholine that could indicate the dysfunction of motor end plates and in turn lead to MTrPs due to the shortening of localized sarcomeres (Hong and Simons, 1998, McPartland and Simons, 2006).

Identification of MTrPs is often achieved through palpation of the affected area. However the reliability of such examinations is poor and only moderate evidence for palpation of m. trapezius, m. gluteus medius and m. quadratus lumborum for local tenderness and pain has been found (Myburgh et al., 2008). Gerwin et al.,(1997) investigated the inter-rater reliability of the physical examination in the diagnosis of MTrPs with similar results showing that the identification of MTrPs in different muscles varies.

Roach et al., (2013) found a correlation between patients with patello femoral pain (PFP) and the presence of MTrPs. Subjects with PFP was significantly weaker in the hip adductors and had a higher prevalence of MTrPs in m. gluteus medius and m. quadratus lumborum compared to a control group. However the trigger point pressure release therapy did not increase force production among the subjects with PFP (Roach et al., 2013). Another study compared Swedish massage and myofascial release therapy in patients diagnosed with Fibromyalgia. Although no significant differences were found trends indicated that the myofascial release therapy lead to more consistent reductions of pain in the neck and upper back regions (Liptan et al., 2013). Further on myofascial release had the same positive effect on passive flexion, extension and abduction gleno-humeral joint ROM as a hot pack application treatment (Kain et al., 2011).

**Self-myofascial release**

Self-myofascial release (SMR) is a type of self-massage where you use your own bodyweight to move around on a roll or ball to loosen up tight areas of the muscle. The hypothesis is that
by performing SMR you treat myofascial restrictions, improve muscle and soft tissue extensibility and regain muscle strength (Fredericson and Wolf, 2005). The positive effects of SMR also includes the improving of muscular function and performance and also effects overuse and joint range of motion (ROM) (Macdonald et al., 2012). Other research also indicated that performing SMR with a foam roller improved arterial and endothelial function, and reduced arterial stiffness on healthy but sedentary subjects (Okamoto et al., 2013).

Healey et al., (2013) found no acute effect after performing foam rolling, positively nor negatively, on jumping performance in comparison with holding a plank. However the planking exercise induced significantly greater fatigue than the foam rolling among the subjects. Further on SMR lead to a significantly increase in ROM in the sit and reach test after performing only ten and five second bouts of foam rolling on mm. hamstrings whereas the ten second bout showed the biggest increase (Sullivan et al., 2013). Another recent study on SMR found that two one minute bouts of foam rolling on the quadriceps muscle resulted in an acute increase of subjects knee joint ROM (Macdonald et al., 2012). This contradicts the results from a study by Miller and Rockey (2006). They found no long term increase in ROM after eight week foam rolling intervention period. The subjects performed three one minute bouts of foam rolling on the hamstrings muscle group three times a week during the intervention but no increase in knee joint ROM was found. On the other hand a study by Sherer (2013) found that after four weeks of foam rolling on mm. hamstrings the flexibility had increased significantly. In the study performed by Macdonald et al., (2012) they did not only found that two one-minute bouts of foam rolling on mm. quadriceps increased the ROM significantly but also that the SMR treatment didn’t impair the subjects rate of force development nor the muscular force as tested by knee extensions. Similar results was found in the study by Sullivan et al., (2013) where no significant changes in maximal voluntary contraction (MVC) force nor muscle activity was seen after the rolling intervention compared to control. Finally a study investigated the use of foam rolling as a recovery tool after performing ten sets of ten repetitions of squats at 60% of 1RM to induce delayed onset muscle soreness (DOMS). The foam rolling group had significantly reduced DOMS and significantly larger ROM compared to control. Muscle activation and force was also significantly reduced by less than control and the foam rolling group also reduced their counter movement jump height significantly less than control (MacDonald et al., 2013).

The type of roller used for the SMR could possibly impact the outcome of the treatment. Two different myofascial rollers exerted different amount of pressure on the soft tissue. The
researchers concluded that the roller that exerted more pressure might be more beneficial in myofascial release and treatment of adhesions (Curran et al., 2008).

A few undergraduate studies have been conducted in the area of interest. One of them compared foam rolling with a manual therapy and found that the manual therapy improved the dynamic flexibility on the iliotibial band whereas the foam rolling did not. Neither of the treatment protocols had any effect, positive nor negative, on the counter movement jump performed by the subjects (Sharp, 2012). Another undergraduate study compared foam rolling and static stretching. Both protocols improved hamstrings flexibility and the static stretching significantly reduced the one-legged jump for distance whereas the foam rolling didn’t. Infact, foam rolling increased the one-legged jump for distance and the static strength of the hamstrings musculature compared to control (Amico and Morin, Undated). Fama & Bueti (2011) also tested jumping performance in an undergraduate study and concluded that a dynamic warm up improved the performance in counter movement jump but not in squat jump nor depth jump. The foam rolling warm up showed no improvement in any of the jumping tests.

**Dynamic stretch**

Dynamic stretching is widely recommended to include in a warm-up routine as opposed to static stretching. Static stretching may decrease performance if performed prior to activities that demands high power and force outputs. Dynamic stretching on the other hand may increase performance by causing a positive effect on the neuromuscular system. Therefore it’s recommended to program a warm up with a sub maximal aerobic activity followed by a general and thereafter a sport specific dynamic stretch (Behm and Chaouachi, 2011). A study found that a dynamic stretch improved the vertical jumping performance compared to a static stretch that had a negative effect on the jumping performance (Hough et al., 2009). Holt and Lambourne (2008) found agreeing results showing how a dynamic stretch lead to a greater improvement in vertical jumping performance compared to a static stretch.
Jumping performance

Jumping performance has long been used to measure the athleticism for athletes in all types of competitive sports. The measure of jumping performance is a measure of power which is an essential component for the level of performance in many sports (Blazevich, 2010).

Power is the ability to create force during a short period of time. Power (P) is measured in Watts (W) and is calculated as force (F) measured in Newton (N) times velocity (V) measured in m/s, \( P = F \times V \). (Blazevich, 2010).

The types of jumping exercises popularly used to measure power is the counter movement jump (CMJ) and the squat jump (SJ) which are both vertical jumps. In a study where seven different jump tests were performed the result showed that CMJ and SJ measured with a digital timer and a contact mat had the highest reliability and CMJ had the highest validity in the measuring of power in the lower extremities (Markovic et al., 2004).

When a concentric contraction is preceded by an eccentric contraction the power output is higher than that produced by a concentric contraction alone (Makaruk et al., 2011). This is accomplished due to the physiological factor known as the stretch-shortening cycle (SSC) (Baechle et al., 2008). Traditionally SSC is tested in the jumps CMJ and drop jump.

There are some physiological differences between male and female in bilateral and unilateral exercises for the lower extremities. Females had a higher muscle activity in m. rectus femoris as compared to males when performing a unilateral squat (Zeller et al., 2003). No differences was found among male in muscle activity between a bilateral and a unilateral squat (Jones et al., 2012). However females had higher muscle activity of mm. quadriceps compared to mm. hamstrings and m. gluteus medius in a bilateral squat. In a unilateral squat the muscle activity was the opposite. A higher muscle activity was recorded in mm. hamstrings and m. gluteus medius compared to mm. quadriceps (McCurdy et al., 2010).

Foam rolling is widely used by athletes but the scientific evidence of its supposedly positive effects is limited. This study will try to contribute to the area of interest and hopefully lead to more interesting research topics of the area.
Aim

The aim of this study was to investigate the acute effect of foam rolling and a standardized dynamic stretch warm-up routine on jumping performance.

Research questions

Is there a difference between a standardized foam rolling warm-up routine and a standardized dynamic stretch warm-up routine on jumping performance measured with bilateral and unilateral squat jump? Is there a difference also when analysing men and women separately?

Is there a difference between a standardized foam rolling warm-up routine and a standardized dynamic stretch warm-up routine on jumping performance measured with bilateral and unilateral counter movement jump? Is there a difference also when analysing men and women separately?

Is there a difference between a standardized foam rolling warm-up routine and a standardized dynamic stretch warm-up routine on jumping performance measured with bilateral and unilateral loaded counter movement jump? Is there a difference also when analysing men and women separately?
Method

The study was conducted with a crossover design and performed with randomized control trials. Two different warm-up routines were used before the tests of jumping performance. The tests performed, squat jump (SJ), counter movement jump (CMJ), and loaded counter movement jump (L-CMJ), were high intensity plyometric exercises. Eighteen subjects with a mean age of 24.3 ± 2.8 years, nine male and nine female, were included in the study.

Subjects

All participants (N=18) completed a familiarization test and were thereafter randomly assigned into one of two treatment groups, foam rolling (FR) and dynamic stretch (DS), indicating which one of the two warm-up routines was performed first. The participants were familiar with weight training and assigned from a local gym. Both male and female subjects participated in the study. If a participant had a previous injury in the lower extremities at the time of the study or up to six months prior to the study they were excluded. If any other condition that may have an effect on the results of the jumping tests were observed during the sessions the participant in question were excluded.

Twelve subjects completed the study, seven men and five women. Six subjects dropped out before completing all prescribed tests. Three subjects dropped out due to injury, two males, one with shoulder pain and one with hip pain, and one female with low back pain. The remaining three subjects, all females, dropped out due to unspecified reasons (Figure 1).
Observation

All participants were instructed to have enough sleep and not train at a high intensity the day before the tests and avoid any plyometrics during the 72 hours leading up to the tests as according to Baechle et al., (2008). The subjects were instructed to rest ≥72 hours between the sessions to induce proper recovery. Further on no additional caffeine or other performance enhancing substances should be taken prior to the tests.

The FR treatment group completed all jumping tests after a five minute general warm up on a cycle followed by the standardized foam rolling warm-up routine on the first day of testing. On the second day of testing FR performed the same jumping tests. However the same five minute general warm-up on a cycle was followed by a standardized dynamic stretch protocol. The DS treatment group performed the dynamic stretch protocol on the first day of testing and the foam rolling warm-up routine on the second day of testing.

Foam rolling warm-up routine
The SMR treatment was performed using a foam roller and a standardized foam-rolling warm-up routine (FR). One minute of foam rolling was performed on each of the following muscle groups; mm. gluteus, mm. hamstrings, mm. triceps surae, mm. quadriceps, the adductor muscle group and m. tensor fasciae latae with the iliotibial band on both extremities.
for a total of 12 minutes. The treatment was performed unilaterally and the foam rolling started at the origin of the muscle and subjects thereafter was instructed to perform the foam rolling with a consistent pace and pressure to the insertion of the muscle and then back continuously for one minute (Appendix 1).

**Dynamic stretch warm-up routine**
The standardized dynamic stretch warm-up routine (DS) consisted of ten repetitions on each leg with a walk back recovery. The exercises was, as used by Holt and Lambourne (2008), ten walking lunges, targeting mainly mm. gluteus, mm. hamstrings and mm. quadriceps. Ten reverse lunges, targeting mainly mm. quadriceps. Ten single-leg Romanian deadlifts, targeting mainly mm. gluteus and mm. hamstrings. Ten straight leg kicks, targeting mainly mm. iliopsoas and mm. hamstrings. To include all muscle groups that were treated with the SMR additional exercises were added for mm. triceps surae, the adductors and the tensor fascia lata and the iliotibial band. Ten repetitions of scissor swings, targeting mainly the adductor muscle group, tensor fascia latae and iliotibial band. Ten repetitions of calf raise, targeting mm. triceps surae. The standardized dynamic stretch warm-up routine lasted for a total of 12 minutes (Appendix 2).

**Tests**
After completing the respective warm-up routine the participants rested for three minutes before conducting the tests of performance. The tests used in this study were SJ, CMJ and L-CMJ. All tests were performed both bilaterally and unilaterally. SJ and CMJ were measured using a force plate, L-CMJ was measured with a linear encoder. All vertical jumps were performed to the depth of a half squat were the knees were bent at approximately 90 degrees. This was obtained by instructing the participants to bend down into a half squat. Each jump was supervised by a trainer to ensure a proper execution of each jump. SJ and CMJ measured with a contact mat and a digital timer are the most valid and reliable tests to measure power in the lower extremities (Markovic et al., 2004). Slinde et al., (2008) found that CMJ performed on a contact mat had a very high test-retest reliability. CMJ has been shown to be both valid and reliable to measure jumping performance among both men (Markovic et al., 2004) and women (Slinde et al., 2008). Markovic et al., (2004) found that the increased coordinative demands that the jumping test standing long jump (SLJ) placed on the subjects created a
motor learning effect. SLJ is also considered to be a valid and reliable method to measure jumping performance however due to the motor learning effect it was suggested that the subjects performed at least one maximal practice trial prior to the tests (Markovic et al., 2004). With this in mind it was decided to include a familiarization test in this study as well prior to the tests. The familiarization test consisted of practicing the movements of the two warm-up routines as well as practicing all of the different jump tests. At the execution of the jumping tests all subjects were instructed to try to jump as high as possible to perform at their best (McBride et al., 2002). On the day of testing the subjects performed three trials on each jumping exercise, with five to ten seconds rest between jumps and two to three minutes rest between the exercises as suggested by Baechle et al., (2008).

**Squat jump**

SJ was performed on a force plate. The participant started the test standing in a half squat position with the knees in a 90 degrees flexion and holding the hands on the hips. On a ready signal from the test leader the subject was instructed to jump as high as possible only using the legs. The best result measured as the highest jump in cm out of three trials bilaterally (SJ FR, SJ DS) and unilaterally, right leg (SJ R FR, SJ R DS) and left leg (SJ L FR, SJ L DS) respectively was collected and included in the study (Fig. 2).

![Figure 2. Squat jump performed bilaterally (A) and unilaterally (B).](image)
Counter movement jump
CMJ was performed on a force plate. The subject started the test standing up straight with the hands on the hips. On a ready signal from the test leader the participant lowered himself down as fast as possible into a half squat position with the knees bend at 90 degrees thereafter the subject immediately changed direction as fast as possible and jumped as high as possible only using the legs. The best result measured as the highest jump in cm out of three trials bilaterally (CMJ FR, CMJ DS) and unilaterally, right leg (CMJ R FR, CMJ R DS) and left leg (CMJ L FR, CMJ L DS) respectively was collected and included in the study (Figure 3).

Figure 3. Counter movement jump performed bilaterally (A) and unilaterally (B).

Loaded counter movement jump
Loaded counter movement jumps (L-CMJ) was performed in a smith machine with a barbell on the subject’s shoulders. The performance was measured using a linear encoder (Musclelab, Ergotest Technology, Norway). The measure of power output using a smith machine and a linear encoder was performed successfully by Crow et al., (2012) and a linear encoder was considered both valid and reliable when measuring power output (Cronin et al., 2004, Hansen et al., 2011). L-CMJ was performed with the same instructions as CMJ with the difference that the subject had a barbell on their back and placed their hands on the barbell. The barbell attached to the smith machine weighed 24 kilograms (kg). Each subject performed three repetitions each bilaterally with, 24kg, 44kg and 64kg for women and 44kg, 64kg and 84kg
bilateral for males. Thereafter three repetitions was performed unilaterally on both left and right leg with 24kg, 34kg and 44kg for women and 34kg, 44kg and 54kg for males. The repetition with the highest concentric power output on each load was documented. (Figure 4).

![A:](image1) ![B:](image2)

**Figure 4:** Loaded counter movement jump performed bilaterally (A) and unilaterally (B).

**Statistics**

IBM SPSS (version 20) and Microsoft Office Excel 2013 (Microsoft) was used to analyze all results. A Shapiro-Wilks test was conducted to test for the normality of data and when the data was considered normally distributed the results were reported as mean value with standard deviation. Data were analysed for the total sample but also stratified by sex. A dependent T-test was used to determine differences between means of the results between the foam rolling warm up routine and the dynamic stretch warm-up routine. The priori alpha level was set at $p \leq 0.05$ for statistical significance.
Ethics and social considerations

All personal information concerning the subjects was collected and kept confidential. All subjects signed an informed consent before conducting the tests (Appendix 3). The participation in the study was voluntary and the subjects could at any time decide to leave without giving a reason.

The findings from this study will help us by giving more information regarding SMR and foam rolling and its effects compared to dynamic stretching. The result will help trainers and physiotherapists prescribe appropriate methods to athletes as well as the general population to an efficient warm-up routine prior to performing physical activities and with that help the population improve their general physical preparedness and general status of health.
Results

Twelve subjects, seven male and five female, age ranging from 21 to 31 years completed all tests and were included in the analysis of the results (Table 1).

Table 1. Subject characteristics

<table>
<thead>
<tr>
<th></th>
<th>All, n=12 mean (SD)</th>
<th>Men, n=7 mean (SD)</th>
<th>Women, n=5 mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>25.1 ± 3.0</td>
<td>25.1 ± 2.6</td>
<td>25.0 ± 3.7</td>
</tr>
<tr>
<td>Height, cm</td>
<td>175.8 ± 8.7</td>
<td>181.9 ± 4.3</td>
<td>167.2 ± 4.7</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>71.8 ± 6.5</td>
<td>76.1 ± 4.4</td>
<td>65.8 ± 3.3</td>
</tr>
</tbody>
</table>

Squat jump

A near statistical significant difference (p = 0.057) was found between the interventions in favor of the standardized dynamic stretch warm-up routine in SJ performed bilaterally for the whole group (n=12). The mean (SD) jumping height for the whole group for SJ FR was 29.3 ± 8.7 cm and for SJ DS 30.5 ± 9.9 cm. No statistical significant differences were found in the unilateral SJ between interventions (Table 2 and Figure 5).

Table 2. Comparison of means in SJ (dependent T-test) between the foam rolling (FR) and the dynamic stretch (DS) intervention in the total sample (n=12).

<table>
<thead>
<tr>
<th>Test</th>
<th>Minimum (cm)</th>
<th>Maximum (cm)</th>
<th>Mean (cm)</th>
<th>Std. Deviation</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>SJ FR</td>
<td>16.7</td>
<td>42.9</td>
<td>29.3</td>
<td>8.7</td>
<td>0.057</td>
</tr>
<tr>
<td>SJ DS</td>
<td>17.6</td>
<td>46.7</td>
<td>30.5</td>
<td>9.9</td>
<td></td>
</tr>
<tr>
<td>SJ R FR</td>
<td>7.1</td>
<td>22.8</td>
<td>15.1</td>
<td>5.9</td>
<td>0.952</td>
</tr>
<tr>
<td>SJ R DS</td>
<td>8.2</td>
<td>23.5</td>
<td>15.1</td>
<td>5.8</td>
<td></td>
</tr>
<tr>
<td>SJ L FR</td>
<td>6.3</td>
<td>22.3</td>
<td>14.5</td>
<td>5.6</td>
<td>0.849</td>
</tr>
<tr>
<td>SJ L DS</td>
<td>7.6</td>
<td>25.0</td>
<td>14.4</td>
<td>5.9</td>
<td></td>
</tr>
</tbody>
</table>

Figure 5. Mean jump height and SD (cm) for all subjects (n=12) of squat jump (SJ) on both legs, right leg and left leg with the foam rolling warm up routine (SJ FR, SJ R FR, SJ L FR) and with the dynamic stretch warm up routine (SJ DS, SJ R DS, SJ L DS).

Data were split into one male group and one female group to further analyze the results. A statistical significant difference between interventions was found for SJ performed bilaterally (p = 0.009) in the male group (n=7) in favor of the standardized dynamic stretch warm-up routine. The mean (SD) jumping height for the males in SJ FR was 35.6 ± 4.7 cm and in SJ DS 37.9 ± 5.2 cm (Table 3 and Figure 6).

Table 3. Comparison of means in SJ (dependent T-test) between the foam rolling (FR) and the dynamic stretch (DS) intervention in the male group (n=7). * = p≤0.05

<table>
<thead>
<tr>
<th>Test</th>
<th>Minimum (cm)</th>
<th>Maximum (cm)</th>
<th>Mean (cm)</th>
<th>Std. Deviation</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>SJ FR</td>
<td>30.0</td>
<td>42.9</td>
<td>35.6</td>
<td>4.7</td>
<td>0.009*</td>
</tr>
<tr>
<td>SJ DS</td>
<td>31.3</td>
<td>46.7</td>
<td>37.9</td>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td>SJ R FR</td>
<td>15.3</td>
<td>22.8</td>
<td>19.5</td>
<td>3.0</td>
<td>0.791</td>
</tr>
<tr>
<td>SJ R DS</td>
<td>14.2</td>
<td>23.5</td>
<td>19.3</td>
<td>3.4</td>
<td></td>
</tr>
<tr>
<td>SJ L FR</td>
<td>12.8</td>
<td>22.3</td>
<td>18.5</td>
<td>3.3</td>
<td>0.940</td>
</tr>
<tr>
<td>SJ L DS</td>
<td>12.4</td>
<td>25.0</td>
<td>18.4</td>
<td>4.2</td>
<td></td>
</tr>
</tbody>
</table>


Figure 6: Mean jump height and SD (cm) for the male group (n=7) of squat jump (SJ) on both legs, right leg and left leg with the foam rolling warm up routine (SJ FR, SJ R FR, SJ L FR) and with the dynamic stretch warm up routine (SJ DS, SJ R DS, SJ L DS).
In the female group (n=5) there were no statistical significant differences found between the two interventions (Table 4 and Figure 7).

Table 4: Comparison of means in SJ (dependent T-test) between the foam rolling (FR) and the dynamic stretch (DS) intervention in the female group (n=5).

<table>
<thead>
<tr>
<th>Test</th>
<th>Minimum (cm)</th>
<th>Maximum (cm)</th>
<th>Mean (cm)</th>
<th>Std. Deviation</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>SJ FR</td>
<td>16.7</td>
<td>22.8</td>
<td>20.4</td>
<td>2.5</td>
<td>0.835</td>
</tr>
<tr>
<td>SJ DS</td>
<td>17.6</td>
<td>22.6</td>
<td>20.3</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>SJ R FR</td>
<td>7.1</td>
<td>11.1</td>
<td>8.9</td>
<td>1.5</td>
<td>0.347</td>
</tr>
<tr>
<td>SJ R DS</td>
<td>8.2</td>
<td>10.6</td>
<td>9.2</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>SJ L FR</td>
<td>6.3</td>
<td>10.0</td>
<td>8.9</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>SJ L DS</td>
<td>7.6</td>
<td>9.9</td>
<td>8.7</td>
<td>0.9</td>
<td>0.694</td>
</tr>
</tbody>
</table>


Figure 7: Mean jump height and SD (cm) for the female group (n=5) of squat jump (SJ) on both legs, right leg and left leg with the foam rolling warm up routine (SJ FR, SJ R FR, SJ L FR) and with the dynamic stretch warm up routine (SJ DS, SJ R DS, SJ L DS).

Counter movement jump

No statistical significant differences were found between interventions of a standardized foam rolling warm-up routine and a standardized dynamic stretch warm-up routine in CMJ for the whole group (n=12), see Table 5 and Figure 8.

Table 5: Comparison of means in CMJ (dependent T-test) between the foam rolling (FR) and the dynamic stretch (DS) intervention in the total sample (n=12).

<table>
<thead>
<tr>
<th>Test</th>
<th>Minimum (cm)</th>
<th>Maximum (cm)</th>
<th>Mean (cm)</th>
<th>Std. Deviation</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMJ FR</td>
<td>15.7</td>
<td>48.4</td>
<td>32.8</td>
<td>11.2</td>
<td>0.138</td>
</tr>
<tr>
<td>CMJ DS</td>
<td>17.4</td>
<td>53.5</td>
<td>34.0</td>
<td>12.1</td>
<td></td>
</tr>
<tr>
<td>CMJ R FR</td>
<td>6.6</td>
<td>24.5</td>
<td>15.9</td>
<td>6.7</td>
<td>0.574</td>
</tr>
<tr>
<td>CMJ R DS</td>
<td>6.3</td>
<td>25.5</td>
<td>15.6</td>
<td>6.6</td>
<td></td>
</tr>
<tr>
<td>CMJ L FR</td>
<td>5.2</td>
<td>24.9</td>
<td>15.3</td>
<td>6.9</td>
<td>0.756</td>
</tr>
<tr>
<td>CMJ L DS</td>
<td>5.5</td>
<td>24.8</td>
<td>15.2</td>
<td>7.0</td>
<td></td>
</tr>
</tbody>
</table>
CMJ = counter movement jump. FR = foam rolling. DS = dynamic stretch. R = right leg. L = left leg.

**Figure 8**: Mean jump height and SD (cm) for all subjects (n=12) of counter movement jump (CMJ) on both legs, right leg and left leg with the foam rolling warm up routine (CMJ FR, CMJ R FR, CMJ L FR) and with the dynamic stretch warm up routine (CMJ DS, CMJ R DS, CMJ L DS).

Data were split into one male group and one female group to further analyze the results. No significant differences were found between interventions among the males (n=7), see Table 6 and Figure 9.

**Table 6**: Comparison of means in CMJ (dependent T-test) between the foam rolling (FR) and the dynamic stretch (DS) intervention in the male group (n=7).

<table>
<thead>
<tr>
<th>Test</th>
<th>Minimum (cm)</th>
<th>Maximum (cm)</th>
<th>Mean (cm)</th>
<th>Std. Deviation</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMJ FR</td>
<td>30.3</td>
<td>48.4</td>
<td>40.8</td>
<td>6.5</td>
<td>0.173</td>
</tr>
<tr>
<td>CMJ DS</td>
<td>29.4</td>
<td>53.5</td>
<td>42.5</td>
<td>7.7</td>
<td></td>
</tr>
<tr>
<td>CMJ R FR</td>
<td>16.2</td>
<td>24.5</td>
<td>20.9</td>
<td>3.1</td>
<td>0.384</td>
</tr>
<tr>
<td>CMJ R DS</td>
<td>14.3</td>
<td>25.5</td>
<td>20.2</td>
<td>4.3</td>
<td></td>
</tr>
<tr>
<td>CMJ L FR</td>
<td>14.3</td>
<td>24.9</td>
<td>20.5</td>
<td>3.4</td>
<td>0.647</td>
</tr>
<tr>
<td>CMJ L DS</td>
<td>12.2</td>
<td>24.8</td>
<td>20.1</td>
<td>4.6</td>
<td></td>
</tr>
</tbody>
</table>

CMJ = counter movement jump. FR = foam rolling. DS = dynamic stretch. R = right leg. L = left leg.
Figure 9: Mean jump height and SD (cm) for the male group (n=7) of counter movement jump (CMJ) on both legs, right leg and left leg with the foam rolling warm up routine (CMJ FR, CMJ R FR, CMJ L FR) and with the dynamic stretch warm up routine (CMJ DS, CMJ R DS, CMJ L DS).

In the female group (n=5) no statistical significant differences were found between interventions (Table 7 and Figure 10).

Table 7. Comparison of means in CMJ (dependent T-test) between the foam rolling (FR) and the dynamic stretch (DS) intervention in the female group (n=5).

<table>
<thead>
<tr>
<th>Test</th>
<th>Minimum (cm)</th>
<th>Maximum (cm)</th>
<th>Mean (cm)</th>
<th>Std. Deviation</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMJ FR</td>
<td>15.7</td>
<td>24.8</td>
<td>21.7</td>
<td>3.8</td>
<td>0.649</td>
</tr>
<tr>
<td>CMJ DS</td>
<td>17.4</td>
<td>24.5</td>
<td>21.9</td>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td>CMJ R FR</td>
<td>6.6</td>
<td>12.1</td>
<td>9.0</td>
<td>2.2</td>
<td>0.477</td>
</tr>
<tr>
<td>CMJ R DS</td>
<td>6.3</td>
<td>13.7</td>
<td>9.3</td>
<td>2.7</td>
<td></td>
</tr>
<tr>
<td>CMJ L FR</td>
<td>5.2</td>
<td>10.0</td>
<td>8.2</td>
<td>2.1</td>
<td>0.649</td>
</tr>
<tr>
<td>CMJ L DS</td>
<td>5.5</td>
<td>9.9</td>
<td>8.4</td>
<td>1.8</td>
<td></td>
</tr>
</tbody>
</table>

CMJ = counter movement jump. FR = foam rolling. DS = dynamic stretch. R = right leg. L = left leg.

Figure 10: Mean jump height and SD (cm) for the female group (n=5) of counter movement jump (CMJ) on both legs, right leg and left leg with the foam rolling warm up routine (CMJ FR, CMJ R FR, CMJ L FR) and with the dynamic stretch warm up routine (CMJ DS, CMJ R DS, CMJ L DS).
**Loaded counter movement jump**
All subjects (n=12) performed three repetitions each bilaterally with 24kg, 44kg and 64kg for females (n=5) and 44kg, 64kg and 84kg bilaterally for males (n=7). Thereafter three repetitions was performed unilaterally on both left and right leg with 24kg, 34kg and 44kg for females (n=5) and 34kg, 44kg and 54kg for males (n=7). Several subjects decided not to participate in all of the jumps.

A statistical significant difference (p = 0.022) was found between a standardized foam rolling warm-up routine and a standardized dynamic stretch warm-up routine on jumping performance in the L-CMJ when performed unilaterally on the right leg with an external load of 54kg (n=6) in favor of the standardized dynamic stretch warm-up routine. The mean (SD) concentric power output measured in Watt (W) on the right leg following the foam rolling treatment (L-CMJ R FR 54) were 948.7 ± 88.2 W and following the dynamic stretch treatment (L-CMJ R DS 54) 1032.0 ± 124.3 W. Two additional near statistical significances were found in the L-CMJ. The result for L-CMJ FR 44 was 1320.2 ± 418.7 W and for L-CMJ DS 44 1405.0 ± 471.8 W (p = 0.087) and the result for L-CMJ H FR 34 was 783.9 ± 222.8 and for L-CMJ H DS 34 was 818.1 ± 256.4 (p = 0.076), both in favor of the standardized dynamic stretch warm-up routine. No other statistical significant difference were found (Table 8).
<table>
<thead>
<tr>
<th>Test</th>
<th>N</th>
<th>Mean (Watt)</th>
<th>Std. Deviation</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-CMJ FR 24</td>
<td>5</td>
<td>914.6</td>
<td>96.6</td>
<td>0.494</td>
</tr>
<tr>
<td>L-CMJ DS 24</td>
<td>5</td>
<td>893.0</td>
<td>73.1</td>
<td></td>
</tr>
<tr>
<td>L-CMJ FR 44</td>
<td>12</td>
<td>1320.2</td>
<td>418.7</td>
<td>0.087</td>
</tr>
<tr>
<td>L-CMJ DS 44</td>
<td>12</td>
<td>1405.0</td>
<td>471.8</td>
<td></td>
</tr>
<tr>
<td>L-CMJ FR 64</td>
<td>11</td>
<td>1334.6</td>
<td>486.5</td>
<td>0.228</td>
</tr>
<tr>
<td>L-CMJ DS 64</td>
<td>11</td>
<td>1374.0</td>
<td>548.1</td>
<td></td>
</tr>
<tr>
<td>L-CMJ FR 84</td>
<td>6</td>
<td>1678.9</td>
<td>347.9</td>
<td>0.937</td>
</tr>
<tr>
<td>L-CMJ DS 84</td>
<td>6</td>
<td>1666.9</td>
<td>378.2</td>
<td></td>
</tr>
<tr>
<td>L-CMJ R FR 24</td>
<td>5</td>
<td>554.8</td>
<td>75.6</td>
<td>0.911</td>
</tr>
<tr>
<td>L-CMJ R DS 24</td>
<td>5</td>
<td>551.9</td>
<td>85.9</td>
<td></td>
</tr>
<tr>
<td>L-CMJ L FR 24</td>
<td>4</td>
<td>476.0</td>
<td>43.9</td>
<td>0.110</td>
</tr>
<tr>
<td>L-CMJ L DS 24</td>
<td>4</td>
<td>528.8</td>
<td>64.1</td>
<td></td>
</tr>
<tr>
<td>L-CMJ R FR 34</td>
<td>12</td>
<td>783.9</td>
<td>222.8</td>
<td>0.076</td>
</tr>
<tr>
<td>L-CMJ R DS 34</td>
<td>12</td>
<td>818.1</td>
<td>256.4</td>
<td></td>
</tr>
<tr>
<td>L-CMJ L FR 34</td>
<td>11</td>
<td>800.3</td>
<td>268.8</td>
<td>0.114</td>
</tr>
<tr>
<td>L-CMJ L DS 34</td>
<td>11</td>
<td>835.8</td>
<td>292.5</td>
<td></td>
</tr>
<tr>
<td>L-CMJ R FR 44</td>
<td>11</td>
<td>781.5</td>
<td>254.3</td>
<td>0.733</td>
</tr>
<tr>
<td>L-CMJ R DS 44</td>
<td>11</td>
<td>776.9</td>
<td>277.0</td>
<td></td>
</tr>
<tr>
<td>L-CMJ L FR 44</td>
<td>10</td>
<td>777.7</td>
<td>264.1</td>
<td>0.340</td>
</tr>
<tr>
<td>L-CMJ L DS 44</td>
<td>10</td>
<td>798.7</td>
<td>296.1</td>
<td></td>
</tr>
<tr>
<td>L-CMJ R FR 54</td>
<td>6</td>
<td>948.7</td>
<td>88.2</td>
<td>0.022*</td>
</tr>
<tr>
<td>L-CMJ R DS 54</td>
<td>6</td>
<td>1032.0</td>
<td>124.3</td>
<td></td>
</tr>
<tr>
<td>L-CMJ L FR 54</td>
<td>6</td>
<td>958.4</td>
<td>62.2</td>
<td>0.419</td>
</tr>
<tr>
<td>L-CMJ L DS 54</td>
<td>6</td>
<td>989.6</td>
<td>114.9</td>
<td></td>
</tr>
</tbody>
</table>

L-CMJ = loaded counter movement jump. FR = foam rolling. DS = dynamic stretch. R = right leg. L = left leg.

24 = 24kg. 34 = 34kg. 44 = 44kg. 54 = 54kg. 64 = 64kg. 84 = 84kg.
Discussion

This study aimed to examine the effects of two different warm-up routines on jumping performance. In most cases there were no differences between the two warm-up routines. However, the differences found supported the dynamic stretch warm-up routine to the foam rolling treatment prior to a jumping performance, especially in men. It is suggested to carefully consider whether or not to include SMR in general and foam rolling in particular in the prescribed warm-up routine.

Results discussion

The statistical significant differences found were in favor of the dynamic stretch warm-up routine. Differences were found in the male group performing SJ bilaterally and for L-CMJ performed unilaterally on the right leg with an external load of 54kg, again in favor of DS. A near significance (p = 0.057) was found between SJ FR and SJ DS also in favor of DS. No other statistical significant differences were found, neither in the whole group nor among males or females.

The tests were performed both bilaterally and unilaterally due to the differences in muscle activity during jumps performed on one or two legs (Zeller et al., 2003, Jones et al., 2012, McCurdy et al., 2010). Possibly the warm-up routines could have a different impact on the different characteristics of the jumps since the physiology of SJ and CMJ differs due to the addition of the SSC in CMJ. It seems as if males may benefit from a dynamic stretch warm-up routine when performing squat jump bilaterally, however CMJ showed no significant differences in the group, nor among males or females.

The results from L-CMJ should be interpreted with care since validity issues occurred during the tests. Some subjects hesitated when performing the test which probably affected the outcome. The result showed that the subjects performed better after the dynamic stretch warm-up routine in jumps performed both bilaterally and unilaterally. A statistical significant difference between L-CMJ R FR 54 and L-CMJ R DS 54 (p = 0.022) shows that the males performed better in that unilateral jump after performing the dynamic stretch warm-up routine. A near statistical significant difference was found for L-CMJ R FR 34 and L-CMJ R...
DS 34 (p = 0.076). This test included both males and females and you may argue that the result would have been significant if females were to be excluded. The results among the males were in favor of the dynamic stretch while the results among the females were inconsistent and would therefore affect the result for the whole group. Another near statistical significant difference between interventions in L-CMJ was the results between L-CMJ FR 44 L-CMJ DS 44 (p = 0.087). A bilateral jump that again included both male and female subjects and therefore may have yielded a significance if it only consisted of males. All these results, significant and near significant, was in favor of the dynamic stretch. It may be suggested that a dynamic stretch could have a positive effect on both bilateral and unilateral jumping performance among males. However these results could not be assured. It is suggested to investigate the effects further with more subjects and more tests.

One of the positive effects of a dynamic stretch, which may explain an improved performance, is the positive effect on the neuromuscular system (Behm and Chaouachi, 2011). The cause of the plausible positive effect of SMR is unknown but one of the factors could be an improvement in proprioception among the subjects. A study showed that the roller that exerted higher pressure might be more beneficial in myofascial release and treatment of adhesions (Curran et al., 2008). While this might be true it’s unlikely that any roller can possibly put the amount of pressure on the tissue that is needed to cause any alterations in the tissue (Chaudhry et al., 2008). Therefore the neurophysiological model seems to be the most plausible explanation for the effect caused by myofascial release and SMR (Simmonds et al., 2012, Martínez Rodríguez and Galán del Río, 2013). Based on this information you may argue that one of the factors determining jumping performance could be the effectiveness of the subject’s use of the neuromuscular system and how well you are capable of warming up the system prior to performance. It seems as if a dynamic stretch could be preferred over a foam rolling warm-up routine in that matter. However the results were inconsistent and more research is needed to fully understand the physiology of SMR and foam rolling and how it affects the treated muscle, fascia and potentially the neuromuscular system among male as well as female subjects.

The results among the females were inconsistent. Previous research has shown that there exists a difference in muscle activity between bilateral and unilateral jumps. Unilateral jumps emphasize a higher activity in mm. hamstrings and m. gluteus medius among females (McCurdy et al., 2010), whereas this was not the case among males (Jones et al., 2012). A unilateral jump puts higher demands on overall strength in the lower extremities of the subject.
as well as in the hips to be able to maintain control and balance during the jump. It may be discussed that the strength among the females was insufficient to effectively stabilize the hips and knee. The increased activity in mm. hamstrings, stabilizer of the knee, and m. gluteus medius, stabilizer of the hip, as seen in the study by McCurdy et al., (2010) may indicate an increased need to stabilize the surrounding joints. The female subjects in this study may have lacked sufficient strength as opposed to the males to be able to stabilize the joints and perform at their best in the unilateral jumps. Therefore in the future, research with trained female athletes will be of interest and to compare the results to the general population.

It’s also important to note the unfortunate dropout rate. Of the two groups, FR and DS, the biggest dropout was seen out of FR were only one female remained. This could possibly explain why the results among the females were very inconsistent as opposed to the males.

**Method discussion**

Both male and female subjects participated in the study. Because of the demands that high intensity exercises such as plyometric jumps put on the subjects, the inclusion criteria required the subjects to be familiar with weight training thus the participants were assigned from a local gym. The study design was a randomized controlled trial with the aim to investigate the difference between a dynamic stretch warm-up routine and a foam rolling warm-up routine on jumping performance. The crossover design was chosen to avoid any possible learning effect. A familiarization test was performed due to the same reason as suggested by Markovic et al., (2004). All 18 subjects performed the familiarization but only 12 completed all tests. The subjects were assigned to their respective groups prior to the familiarization. Five out of the six subjects dropped out before conducting any of the tests and the remaining drop out participated in two sessions out of three, including the familiarization. Of the two groups, FR and DS, the biggest dropout was seen out of FR were only one female remained. Despite the unfortunate dropouts a near significance (p = 0.057) was found between SJ FR and SJ DS in favor of DS. It’s possible that the difference would have been significant if the population of the study would have been bigger. Although when the group was split into genders the difference between SJ FR and SJ DS was significant among the males whereas among the females the difference between SJ and SJ DS had a p-value of 0.835.
You may argue that the randomization of the groups should have been performed after the familiarization to avoid the plausible negative effect the unfortunate dropouts had for the FR group. However, it is not possible to estimate a dropout without compromising the randomization. To avoid a bias and to ensure the randomization the grouping was performed prior to the familiarization.

Both the FR treatment and DS treatment were performed for 12 minutes each. This was due to the FR which lasted for 12 minutes because of the six different muscle groups being treated one minute each unilaterally. One minute on each muscle group was chosen to standardize the time at which the same muscle was under pressure as opposed to performing a set number of repetitions which then would have been hard to ensure that each subject treated the same muscle the same time. The DS treatment however was performed for reps due to the use of the routine in a previous study (Holt and Lambourne, 2008). The exercises that were added were chosen to make sure the DS treatment incorporated all muscle groups that were treated with the foam rolling. Both FR and DS were supervised by a trainer that made sure all participants completed the time and or reps as prescribed.

The aim of the study was to compare foam rolling as a warm-up routine with a dynamic stretch on jumping performance. Dynamic stretching is widely used in warm up routines to increase performance by causing a positive effect on the neuromuscular system. Static stretching on the other hand may even decrease performance if performed prior to activities that demands high power and force outputs (Behm and Chaouachi, 2011) such as SJ and CMJ. It would have been interesting to include a third group, static stretching, in the study to compare the results to dynamic stretch and foam rolling. However multiple studies have shown that a dynamic stretch should be performed instead of a static stretch prior to performance (Hough et al., 2009, Holt and Lambourne, 2008). With a different study aim, for example to investigate the effect on range of motion instead of jumping performance a static stretching protocol would have been suggested.

McBride et al., (2002) discuss how the intention to move a weight as fast as possible is an important factor when aiming to reach a maximum power output. The jump tests in this study are all exercises with a high power output and even though there is no external loading you may suggest that the subject’s intention to jump as high as possible is crucial to reach the highest jump results as possible. The subjects were instructed to try to jump as high as possible to obtain the most reliable results as possible. All jumps in the study were supervised.
by a trainer to make sure the requirements of each jump were meet. The depth of the jumps was set to 90 degrees. To standardize the jumps it was considered to use a goniometer to measure the knee angle to make sure the depth was meet. However it would have been difficult to control that the depth was met in the execution of the jumps. Therefore the participants were instructed to bend down into a half squat to meet the criteria of the jumps. This would make sure that the participants bended down comfortably to be able to perform at their best instead of worrying about meeting the correct depth of the jumps.

All subjects received the same instructions when performing the test that involved an external loading, L-CMJ. However the result should be interpreted with care due to validity issues that occurred during the execution of the tests making it difficult to standardize the test for each subject. The test was performed in a smith machine which height was not sufficient for the subjects to freely jump as high as possible. Several subjects continuously jumped all the way up and violently hit the end of the smith machine. This had a negative impact on the jumping performance of the subjects for several reasons. The results registered from the linear encoder could not be ensured and the data collected was considered unreliable. Subjects hitting the end of the smith machine did not perform at their best in the remaining of the jumps in fear of hitting the end once more. More so even other subjects watching the jump in question hesitated when executing the jumps themselves and performed poorer after witnessing the previous subject hit the end of the smith machine.

The use of a smith machine and a linear encoder to measure power is an effective and proven method to measure jumping performance (Crow et al., 2012, Cronin et al., 2004, Hansen et al., 2011). It is suggested to perform the test again to obtain valid and reliable data to add to the existing research in the area.

The tests was performed both bilaterally and unilaterally due to the differences in muscle activity during jumps performed on one or two legs (Zeller et al., 2003, Jones et al., 2012, McCurdy et al., 2010). Foam rolling could hypothetically have a positive effect on unilateral jumps due to an improvement in proprioception however this could not be seen. The difference between SJ and CMJ due to the addition of SSC during the CMJ did not seem to make a difference for DS nor FR. It’s possible that FR may cause a negative effect on CMJ particularly if performed for a longer duration and causing a relaxation of the muscle spindles and golgi tendon organs and thus decrease the effect of the SSC, however no results could
justify that statement. Further research should investigate the effect of foam rolling and compare the effect of different durations of SMR treatment on jumping performance.

A validity and reliability issue regarding all tests that was considered was if the participants actually performed at their best at the time of the tests. To control this the participants received instructions to have enough sleep and not train at a high intensity the day before the tests and not to perform any plyometrics during the 72 hours leading up to the tests as suggested by Baechle et al., (2008). No additional caffeine or other performance enhancing substances was to be taken prior to the tests.

There are disagreements on how to define fascia and what the fascia really is. This disagreements leads to different definitions of fascia in textbook and research (Schleip et al., 2012). Fascia is complex and looks different in different parts of the body. It’s arguably complicated to study fascia when the characteristics differs from being relatively autonomous to being in continuity with muscle fibers (Findley et al., 2012). When using different methods of myofascial release and SMR you may discuss whether it’s the actual fascia that is treated or if it’s the muscle itself. It is widely accepted to use SMR as a warm-up routine and as a method to treat myofascial restrictions. However the area is poorly researched within the field of sports science. The academic proof of it is very limited and the recommendations are mostly based on anecdotal experience and personal opinions. More research is needed to further shed light on the area of interest.
Conclusion

A dynamic stretch warm-up routine may be preferred instead of a foam rolling treatment prior to performing high intensity plyometric exercises bilaterally especially among males. However the data was inconsistent and more research with larger sample sizes is needed to further investigate the possible effects of foam rolling as a warm-up routine on jumping performance performed both bilaterally and unilaterally.
References


Appendix 1: Foam rolling warm-up routine

A1. A: Foam rolling of mm. gluteus from the origin (A1) to the insertion of the muscles (A2).

B1. B: Foam rolling of mm. hamstrings from the origin (B1) to the insertion of the muscles (B2).

C1. C: Foam rolling of mm. triceps surae from the origin (C1) to the insertion of the muscles (C2).
D: Foam rolling of mm. quadriceps from the origin (D1) to the insertion of the muscles (D2).

E: Foam rolling of the adductors from the origin (E1) to the insertion of the muscles (E2).

F: Foam rolling of m. tensor fascia latae and the iliotibial band from the origin (F1) to the insertion of the muscle (F2).
Appendix 2: Dynamic stretch warm-up routine

A: Walking lunges from start (A1) to finish (A2).

B: Reverse lunges from start (B1) to finish (B2).

C: Single-leg romanian deadlifts from start (C1) to finish (C2).
D: Straight leg kicks from start (D1) to finish (D2).

E: Scissor swings from start (E1) to finish (E2).

F: Calf raise from start (F1) to finish (F2).
Appendix 3: Informed consent

Vill du medverka i min forskningsstudie om Foamrolling?

Hej! Mitt namn är Henrik Årneby och jag studerar Magisterprogrammet - Biomedicin inriktning fysisk träning och prestation på Högskolan i Halmstad. Under min utbildning skriver jag en D-uppsats angående triggerpunktsbehandling och jag hoppas att du vill vara med i min forskningsstudie.

**Bakgrund och syfte**


Syftet med den här studien är att undersöka den akuta effekten av foamrolling på benens muskulatur genom att mäta prestationsförmågan i tre olika hoppövningar och jämföra det med en standardiserad dynamisk stretch.

**Förfrågan om deltagande**

Jag undrar om du som student på Högskolan i Halmstad vill delta i min studie. För att delta så vill jag att du är skadefri och att du inte lider av andra åkommor som kan komma att påverka resultaten, t.ex om du vid testtillfället är sjuk.

**Hur går studien till?**


Du förväntas att inte ha genomfört någon typ av plyometrisk träning, hoppträning, 72 timmar innan testerna samt ingen hård fysisk ansträngning 24 timmar innan testtillfället.
Uppvärmningen vid tillfälle två och tre kommer att skilja sig. Efter en generell uppvärmning på cykel kommer du vid det ena tillfället genomföra en dynamisk stretch och vid det andra tillfället kommer uppvärmningen bestå utav foamrolling. Varje testtillfälle kommer att ta ungefär 90 minuter.

**Vilka är riskerna?**

Hopptesterna är tester där maximal ansträngning krävs. Om du som testperson känner obehag eller smärta ska du omedelbart meddela detta varpå testerna avbryts. Riskerna med testerna anses vara mycket små.

**Finns det några fördelar?**

Genom att studera den direkta effekten av foamrolling på benen vid hopptester så kommer vi att lära oss mer om hur vi kan använda foamrolling i uppvärmningssyfte vilket kan bidra till en bättre förståelse och ge nytt underlag för vilka uppvärmningsrutiner som kan leda till en ökad prestationstörnagemän.

**Hantering av data och sekretess**


**Hur får jag information om studiens resultat?**

Samtliga testdeltagare får vid önskemål tillgång till sina resultat när samtliga testfallen har genomförts. Studien kommer att finnas tillgänglig för samtliga vid publicering. Önskar du ytterligare information om studiens resultat så är du välkommen att höra av dig till mig, se kontaktuppgifter nedan.

**Frivillighet**

Du som testperson har rätt att när som helst under studiens gång avbryta ditt deltagande utan att ange något skäl. Dina redan insamlade data kommer då om du begär detta att förstöras.
Ansvariga

Ansvarig för studien är.
Henrik Årneby

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Har du några frågor angående studien så är du välkommen att höra av dig.

Med vänliga hälsningar
Henrik Årneby
Samtycke till deltagande i forskningsstudie

Nedan ger du ditt samtycke till att delta i den studie där vi utvärderar den direkta effekten av foamrolling på hoppförmågan. Läs igenom detta noggrant och ge ditt medgivande genom att skriva under med din namnteckning längst ned.

Medgivande

Härmed intygar jag att jag läst igenom det informerande samtycket och att jag förstått vad deltagande i studien innebär. Jag är införtstådd med inkluderingskraven och jag ställer frivilligt upp i studien.

______________________________  ________________________________
Namn  Underskrift

______________________________
Datum och ort
Henrik completed his Bachelor’s and Master’s degrees in Sports and Exercise Science at Halmstad University. He endeavours to making athletes and the general population conscious of the importance of strength and conditioning for performance and for the quality of life.